Phosphorus Removal and Recovery from Wastewater

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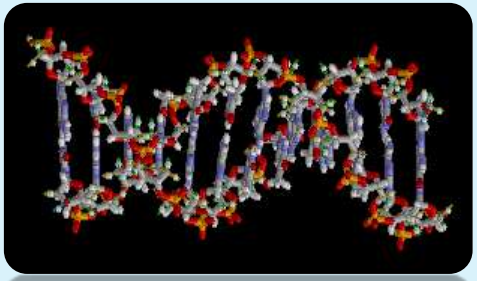
The P Story:

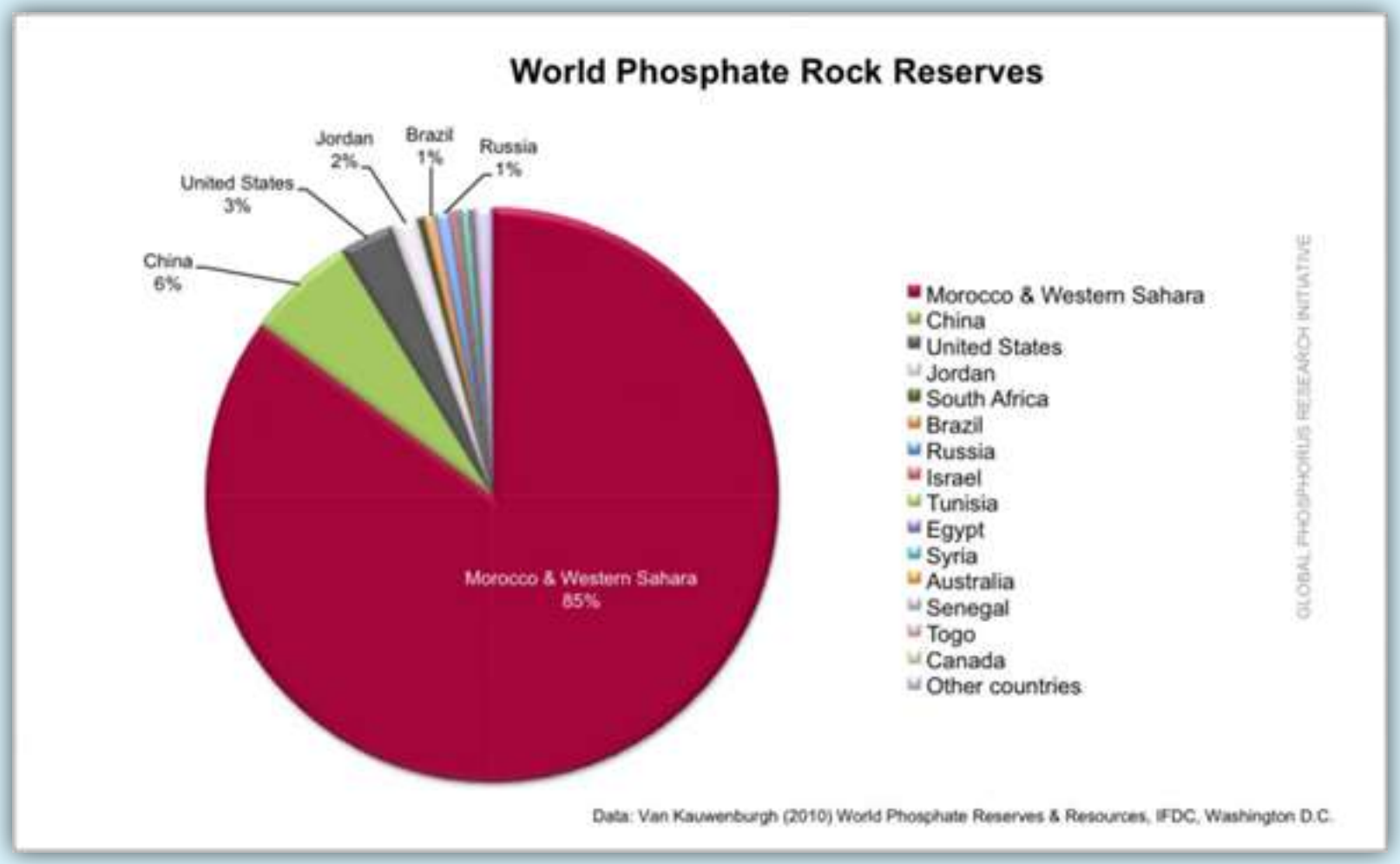
- P is essential to all living organisms
  - DNA
  - Lipid membrane
  - Energy growth and development



- Limited resource
  - Rock phosphate reserves – On the decline
  - ~100 years of minable P remaining

- P and global food security are intrinsically linked
  - Peak P is worrying for global food markets – economy

The P Story:


World Phosphate Rock Reserves
Jordan 2%
Brazil 1%
Russia 1%
United States 3%
China 6%
Morocco & Western Sahara 85%
Morocco & Western Sahara
China
United States
Jordan
South Africa
Brazil
Russia
Israel
Tunisia
Egypt
Syria
Australia
Senegal
Togo
Canada
Other countries
GLOBAL PHOSPHORUS RESEARCH INITIATIVE
Data: Van Kauwenburgh (2010) World Phosphate Reserves & Resources, IFDC, Washington D.C.

Taking Action

- Change of mind-set
  - Overreliance on primary P sources
  - Focus on secondary sources

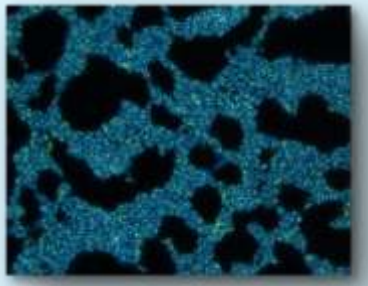
- Wastewater Treatment Plant (WWTP)
  - Rich source of P
  - Human excreta – 3-4g of P per day . . .

- Current technologies struggle to deal with an ever increasing waste load
  - Legislation
  - Expensive chemical treatment - Flocculation
  - Strict operational conditions – Enhanced Biological Phosphorus Removal (EBPR)
  - Environmental health

- There is a niche for new and more efficient P removal and recovery technologies

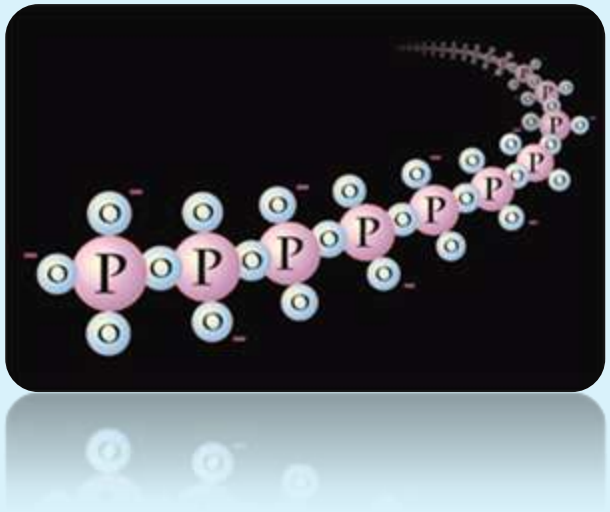
Research at QUB

- Microbiology
  - Exploiting microorganisms natural ability to accumulate P
  - Enhance their capacity for P storage
  - Improve their performance in a WWTP



Intracellular PolyP

- Polyphosphate
  - Biopolymer of tens or hundreds of orthophosphates linked together by phosphoanhydride bonds
  - Motility
  - Virulence
  - Quorum sensing
  - **Survival under stress**



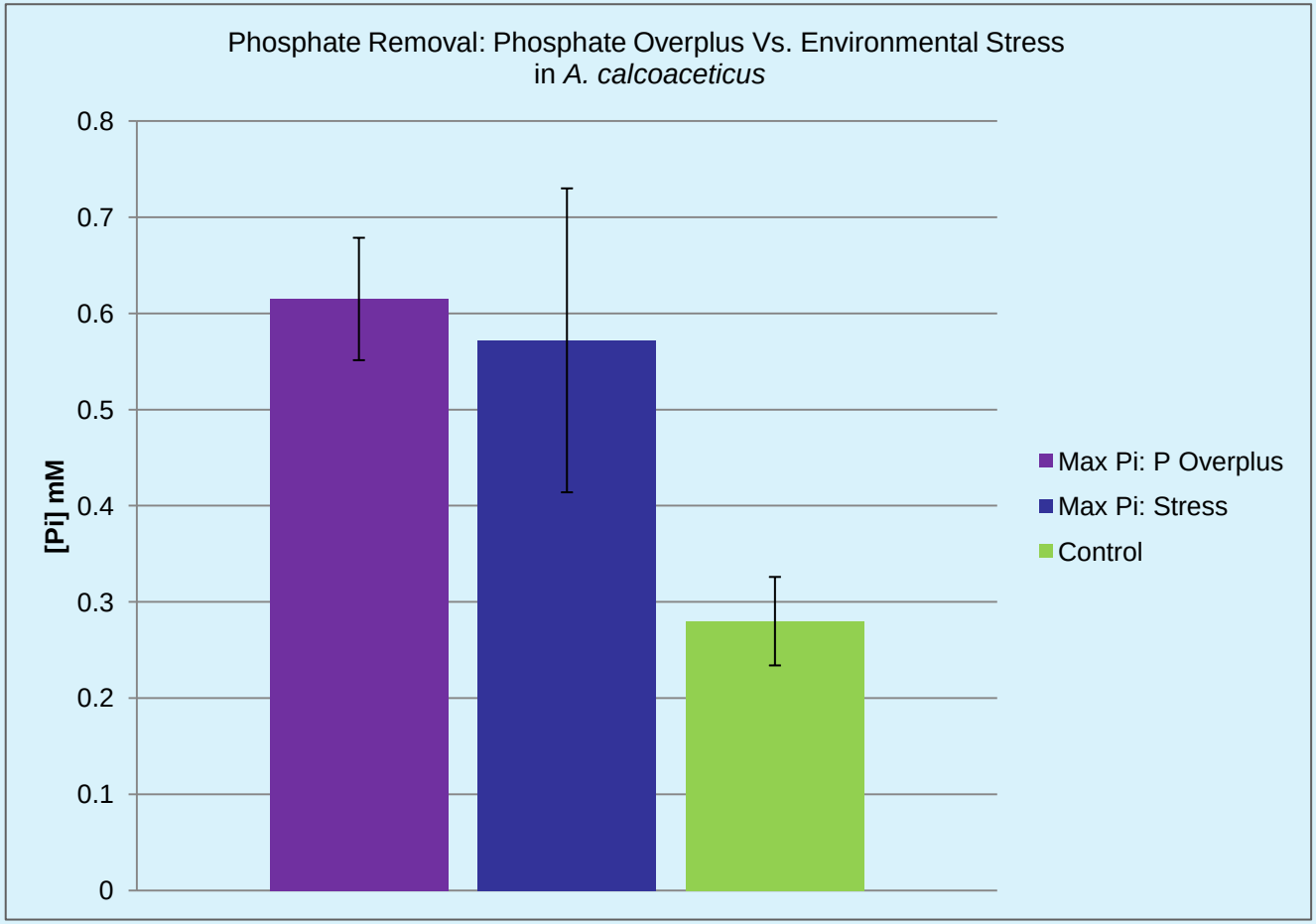
Research at QUB

- Exposing microorganisms to periods of environmental stress results in a rapid uptake of phosphate
  - Polyphosphate accumulating microorganisms (PAOs)
  - *Pseudomonas putida*
  - *Acinetobacter calcoaceticus*
  - Polytox™ (Surrogate wastewater microbial community)

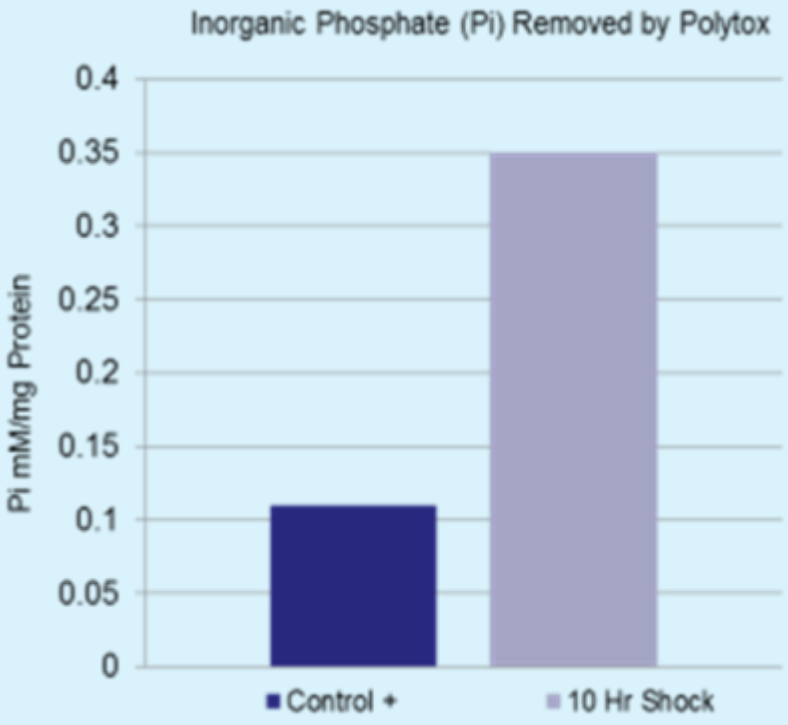
- Stresses include…
  - pH shock
  - Temperature change
  - Aerobic/anaerobic cycling
  - Nutritional deprivation

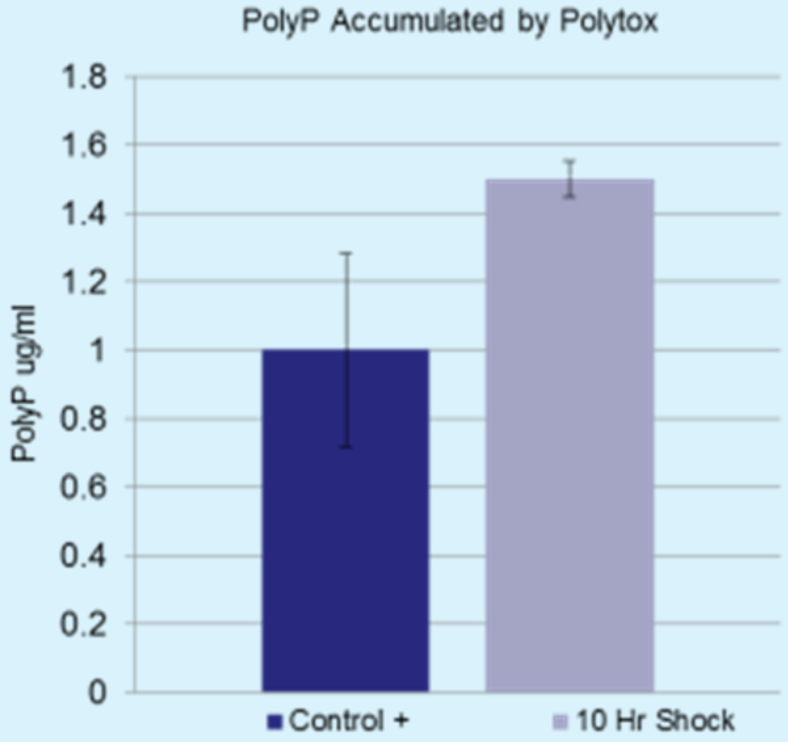
- Up to **300%** increases in phosphate uptake have been observed in response to the stressor

Research at QUB



Research at QUB





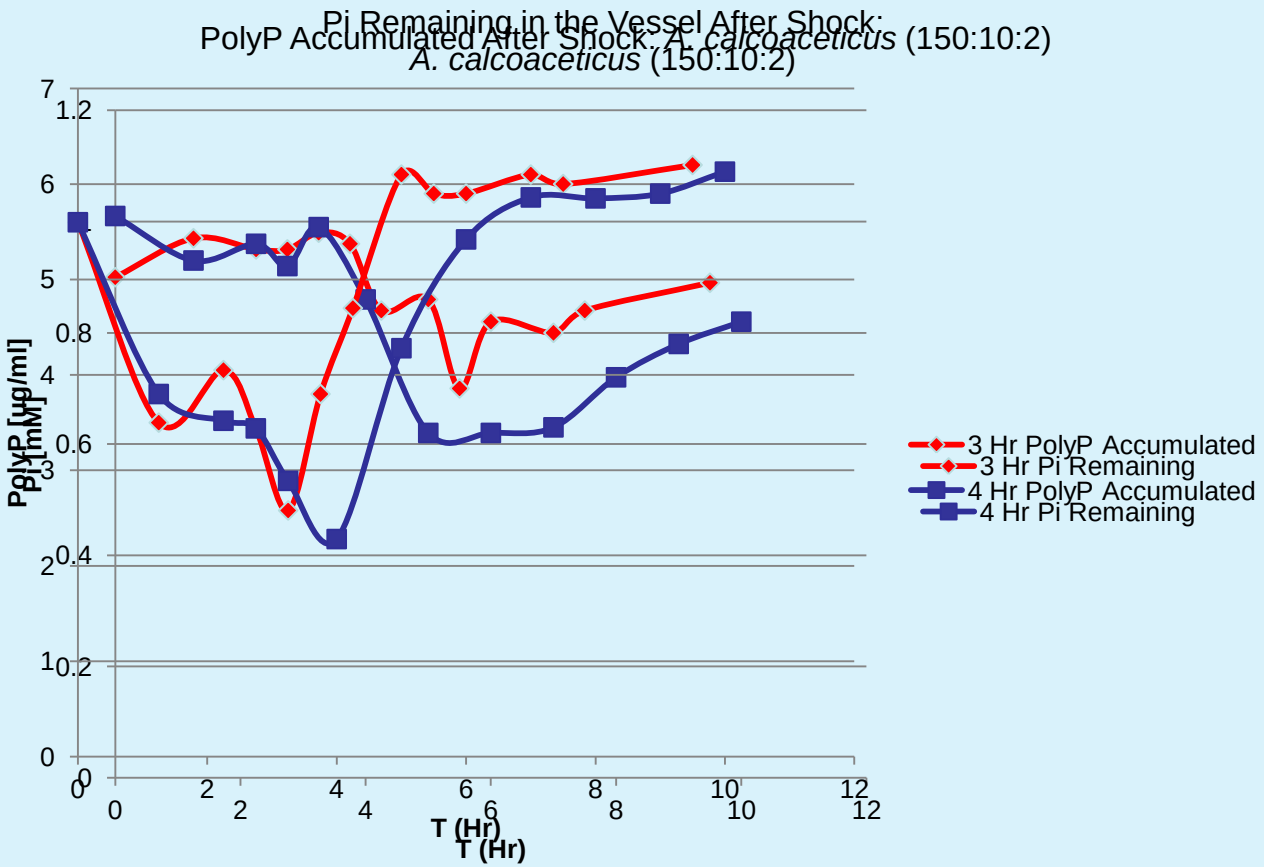
Research at QUB

- The initial studies provided a springboard from which to launce an in-depth investigation
  - Scale-up from bench scale batch to continuous culture
  - 20ml shake flask – 2Ltr state-of-the-art bioreactor

- Bioreactor studies
  - Simulate conditions of a WWTP
  - Manipulation of the environmental conditions
  - Accurate monitoring of the system parameters

- Plans to further up-scale to 20Ltr model WWTP

Research at QUB



Research at QUB

- Further studies are required to understand fully this novel biotechnology
- Biochemical analysis
  - Enzymes involved in polyP synthesis and degradation
  - Signalling molecules involved in the *stringent response* (p)ppGpp
  - Regulatory enzymes – RelA and SpoT
  - The effect of fatty acid synthesis inhibition
    - Chemical compounds
- P budgets and P recovery
  - Not all of the phosphate taken up is converted to polyP
  - Current figures suggest a ~30% conversion
  - Phospholipid membrane, free phosphate, (p)ppGpp, ATP, pyrophosphate . . .
- Metabolomics
  - Relatively new technology in the environmental field
  - Metabolite profile (Nuclear Magnetic Resonance) NMR Spectroscopy and (Mass Spectrometry) MS
  - Gaining an insight to microbial response to stress

Research Impact

- Economical
  - Local
  - National
  - International
- Global P security
  - Sustainable futures
- Improving water quality and environmental health
  - Potability
  - Livestock
  - Aesthetics
- Preserving an invaluable non-renewable research

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